

power tracked sensor unit with an alternative means for obtaining the 3D position of the point source in the PSD. FIG. 12 illustrates a PSD based pose tracking system with a low power tracked sensor unit according to an embodiment of the present invention. As shown in FIG. 12, in this configuration, the PSD tracking device 1200 includes a high power light source 1202 attached to the PSD 1204. In the tracked sensor unit 1210, the LED light source is replaced by a combination of a retroreflector 1212, liquid crystal display (LCD) 1214, and lens assembly 1216. Such a system is different from conventional passive markers, which comprise of just a collection of retroreflective markers that are observed and then identified in a projection image. Since the PSD 1204 generates a signal for the average of all light spots, the modulation of the passive marker is necessary to distinguish its projection from that of others. This complete assembly typically takes a fraction of the power of most efficient LEDs. Alternatively, the lens 1216, LCD 1214, and retro-reflector 1212 combination shown in FIG. 12 can be replaced by a modulating retro-reflector (MRR) and lens combination. Typically MRRs are used in optical communications in which a laser source is used as an interrogator source. In an embodiment of the present invention, an un-collimated, diffused source of light is used to illuminate the retroreflector for all possible directions. The lens 1216 in front of the LCD 1214 or MRR is used to control the view angle. If the LCD 1214 or modulator is off, no light will be returned and thus no light spot will be formed on the PSDs 1204 of the PSD tracking device 1200. If the LCD 1214 or modulator is on, light will pass through the LCD 1214 or modulator and will be reflected back along the same path. This would give the retro-reflector 1212, LCD 1214, and lens 1216 combination an appearance of a “cat’s eye” that can be opened or closed based on modulations of the LCD 1214 or modulator. Note that the optical power of the light source 1202 mounted on the PSD 1204 has to be at least four times that of the equivalent LED mounted on the tracked sensor unit to achieve comparable working distances. This assumes that there are not optical power losses in the LCD 1214, retroreflector 1212, or lens 1216.

[0079] Another alternative is to power the tracked sensor unit wirelessly using existing RFID technology. For example, battery-free ultra high frequency (UHF) RFID LED tags, such as Farsens Stella-LEDW703, are able to wirelessly receive power from UHF and can light up an LED. Additional power for the IMU and processing unit can be supplied with such technology as well.

[0080] Additional variations and extensions to the above described embodiments are provided as follows.

[0081] In a possible embodiment, the PSD tracking device can be equipped with a tracked sensor unit, and the entire tracking chain can be cascaded to increase the size of the workspace where the overall tracking system is operational.

[0082] In a possible embodiment, stationary tracked sensor units can be used to establish a coordinate system that can be used as a frame of reference by one or more PSD tracking devices, so that the PSD tracking devices can be moved and still be able to track other moveable tracked sensor units.

[0083] In a possible embodiment, multiple PSD tracking devices, which may not necessarily be pre-calibrated to each other, may be distributed around the workspace oriented in different directions. The tracked object itself can be used as a means to calibrate these distributed PSD tracking devices.

[0084] In a possible embodiment, miniaturized tracked sensor units can be attached to deformable bodies to track the position and orientation of select points on the instrumented deformable body. Various identification methods, such as flashing frequency and duty cycle of LED strobing, can be used as examples to resolve identification of each of the tracked sensor units by the PSD tracking device.

[0085] The embodiments described above use the earth’s gravity and magnetic north to setup a global coordinate system. In an alternative embodiment, a permanent magnet may be attached to a fixed point (e.g., an ultrasound cart, or patient bed) with sufficient field strength. This permanent magnet may be used as a reference instead.

[0086] The foregoing Detailed Description is to be understood as being in every respect illustrative and exemplary, but not restrictive, and the scope of the invention disclosed herein is not to be determined from the Detailed Description, but rather from the claims as interpreted according to the full breadth permitted by the patent laws. It is to be understood that the embodiments shown and described herein are only illustrative of the principles of the present invention and that various modifications may be implemented by those skilled in the art without departing from the scope and spirit of the invention. Those skilled in the art could implement various other feature combinations without departing from the scope and spirit of the invention.

1. An apparatus for tracking a position and orientation in three-dimensional space of one or more objects, the apparatus comprising:

- one or more tracked sensor units, each tracked sensor unit connected with a respective one of the one or more objects and comprising one or more light sources and an inertial measurement unit;

- one or more position sensitive detector tracking devices, each position sensitive detector tracking device comprising a plurality of position sensitive detector sensors combined with optical lenses that focus light from a field of view onto each position sensitive detector sensor; and

- a processing unit configured to calculate the position and orientation of each of the one or more objects in three-dimensional space from output of the inertial measurement unit of the respective tracked sensor unit and output of the one or more position sensitive detector tracking devices in response to light emitted from the one or more light sources of the respective tracked sensor unit.

2. The apparatus of claim 1, wherein in response to light emitted from a light source of a tracked sensor unit being focused onto each of the plurality of position sensitive detector sensors of a position sensitive detector tracking device, each of the plurality of position sensitive detectors measures a 2D location of the light source of the tracked sensor unit with respect to that position sensitive detector, and the processing unit is configured to triangulate a 3D position of the light source of the tracked sensor based on the 2D locations measured by the plurality of position sensitive detectors.

3. The apparatus of claim 1, wherein each position sensitive detector tracking device further comprises a local inertial measurement unit, and the processing unit is configured to calculate a 3D orientation of each of the one or more objects with respect to each position sensitive detector tracking unit based on orientation measurements from the